Large-Scale Air-Sea Interaction: Remote Influences on Tropical Pacific Variability

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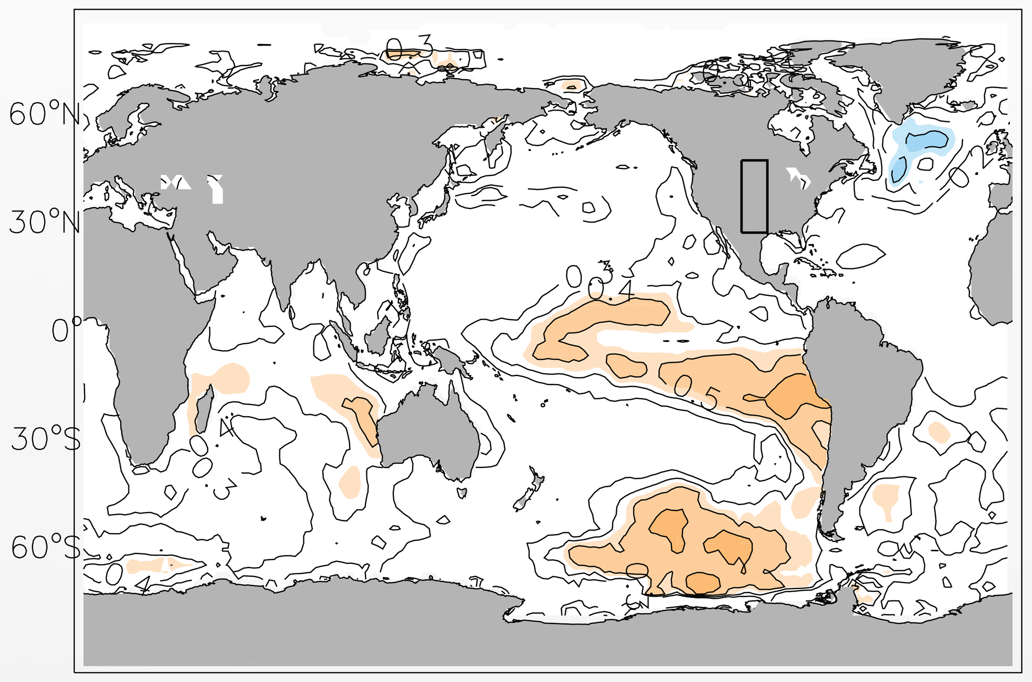
Introduction

PSD scientists conduct a wide-range of studies on large-scale air-sea interaction using observations, models, and theory. We have examined air-sea interactions associated with western boundary currents, the Pacific Decadal Oscillation and ENSO. Here we examine the influence of processes that are initiated from outside the equatorial Pacific on interannual and lower frequency variability in the ENSO region, since the tropical Pacific has a strong impact on global climate variability:

Obs Prec-SST Correlation

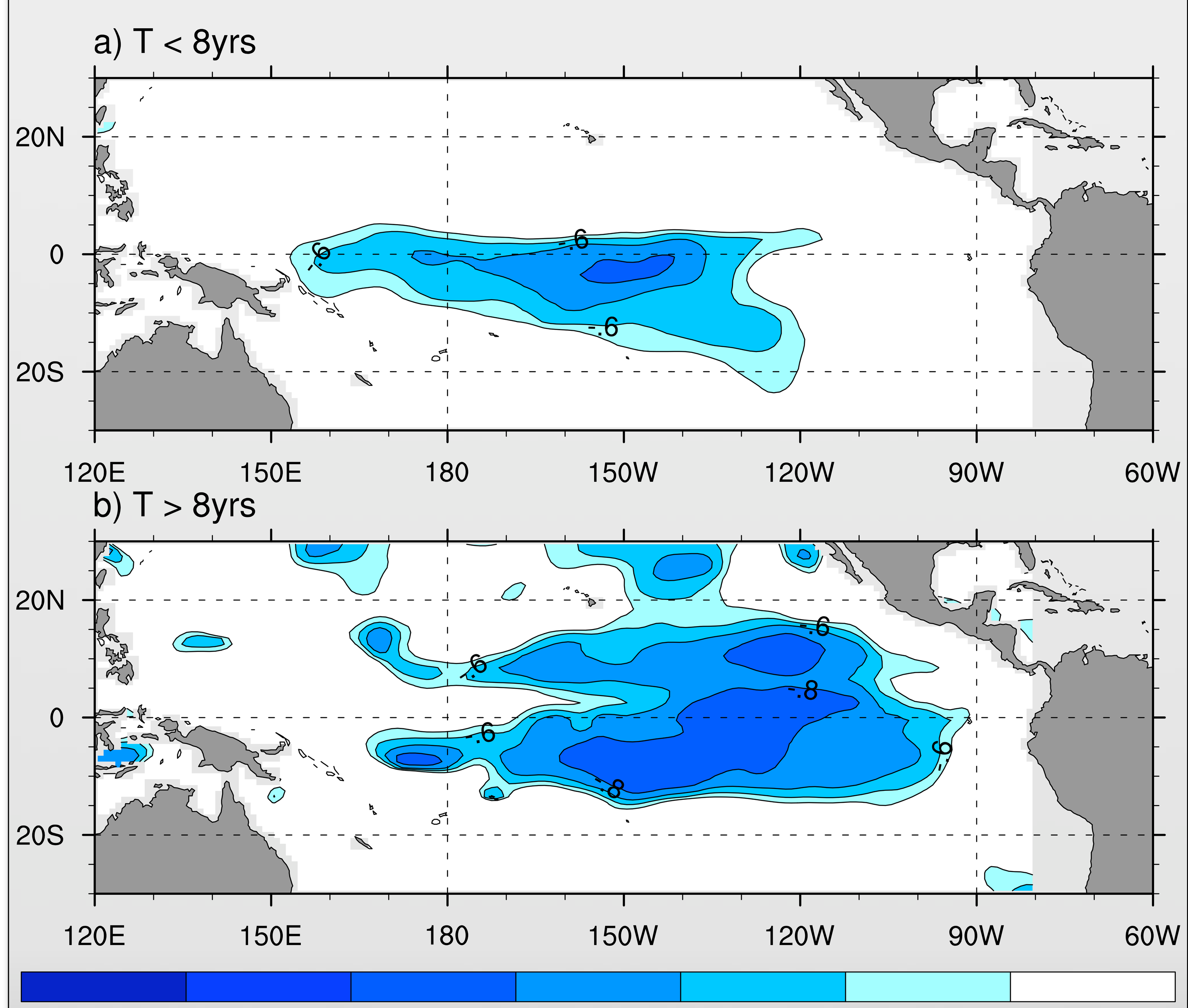


Observed correlations between 5-year running mean precipitation over the Great Plains and SSTs (1900-2008). (Capotondi and Alexander, 2010, J. Climate).

Wind Forcing of the Subtropical Cells

(Capotondi et al. 2005, J. Climate)

Analyses of an OGCM driven by observed surface boundary conditions indicate that upwelling on the equator on interannual time scales is associated with local winds while lower frequency fluctuations of upwelling, and SSTs (correlation between upwelling and SST is ~0.99), are associated with wind variations off the equator, and changes in the strength of the subtropical cells.



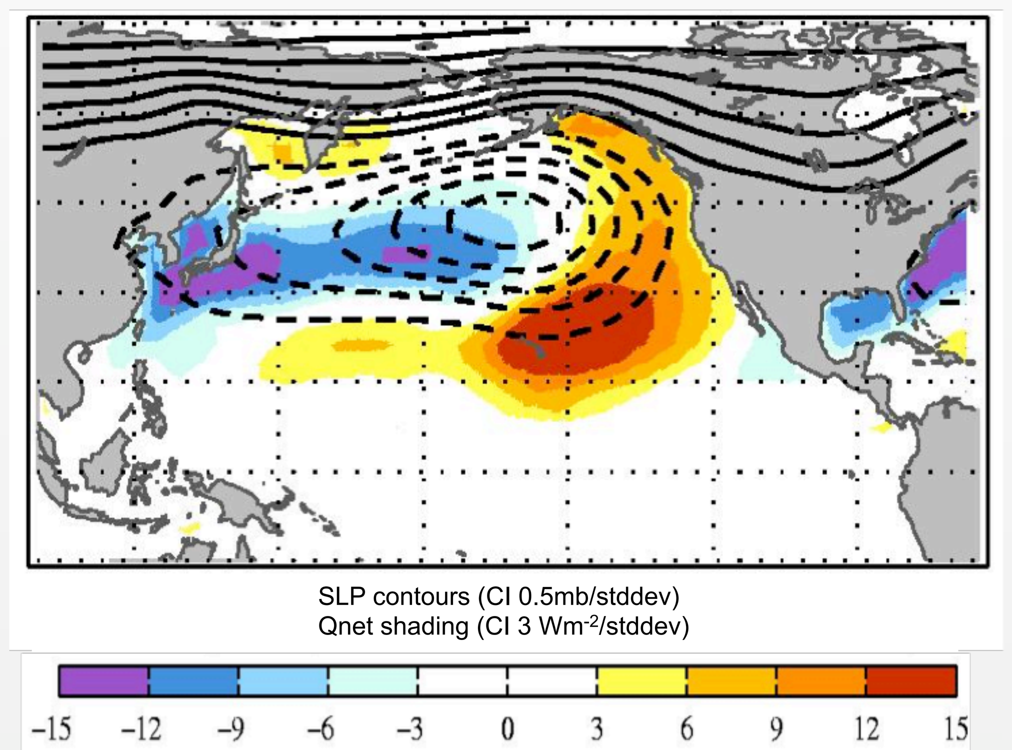
Max lag correlation between zonal wind stress and an upwelling index (average of the vertical velocity at 50-m depth over 1°S–1°N, 180°-90°W), for a) high pass and b) low pass filtered fields.

Seasonal Footprint Mechanism

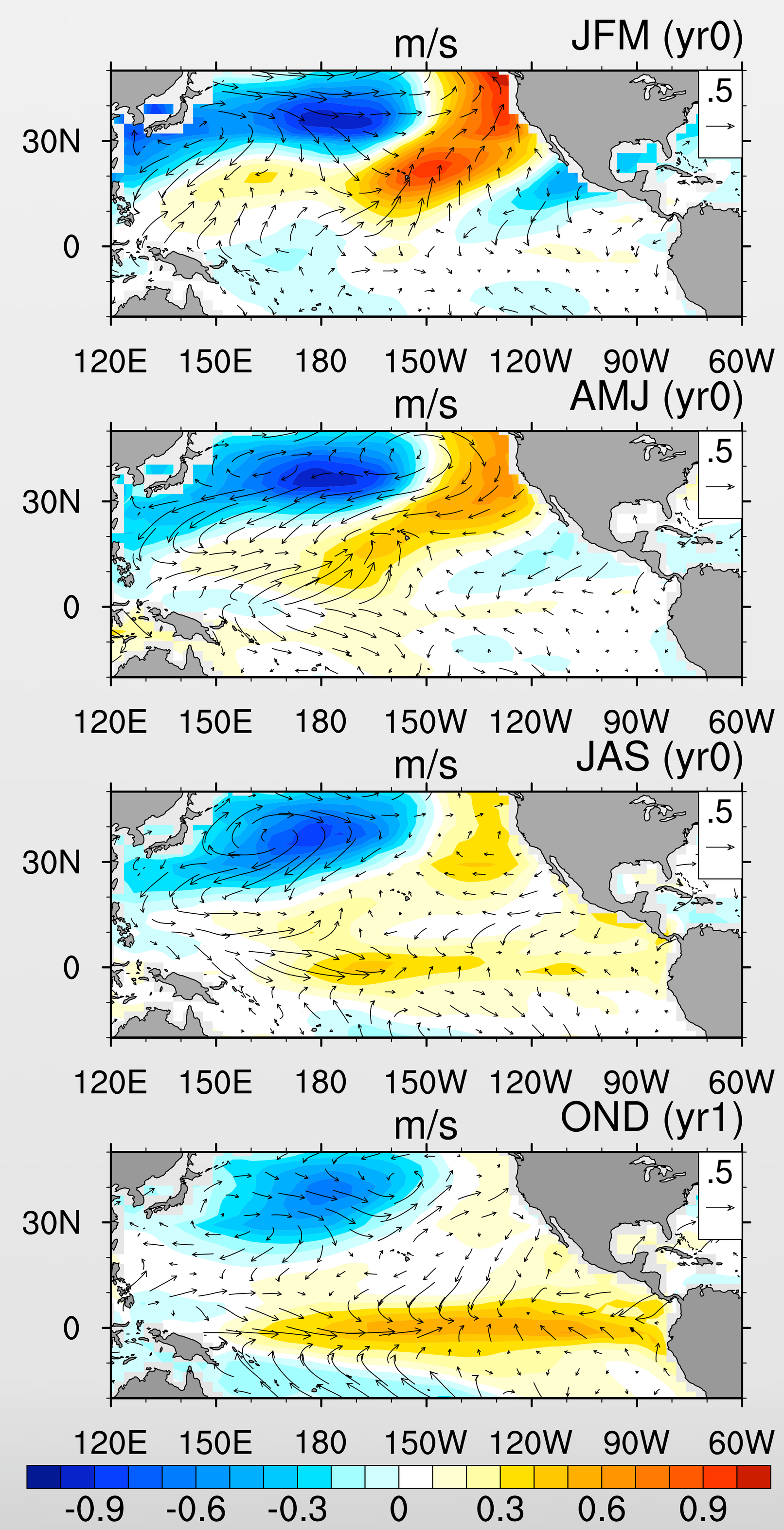
(Vimont et al. 2003, Vimont et al. 2009, Alexander et al. 2010, all in J. Climate)

SFM: *i)* Fluctuations in the North Pacific Oscillation (NPO), a meridional SLP dipole and the second leading pattern of SLP variability over the North Pacific, influence the subtropical ocean via surface heat fluxes during winter. *ii)* The resulting subtropical SST anomalies (footprint) affect the precipitation and winds over the tropics in spring and summer. *iii)* Wind changes in the vicinity of the equator are effective at generating ENSO events in the following winter. We test this mechanism by adding in additional NPO-related heat flux forcing to a coupled model during the first winter and then allowing the model to evolve freely for one more year.

2nd EOF SLP & Qnet Nov-Mar



North Pacific Oscillation, 2nd EOF of SLP over the North Pacific during winter and the associated net surface heat flux into the ocean. The latter, obtained by regressing the heat flux on the 2nd PC of SLP, is used to force the coupled model during the 1st winter.

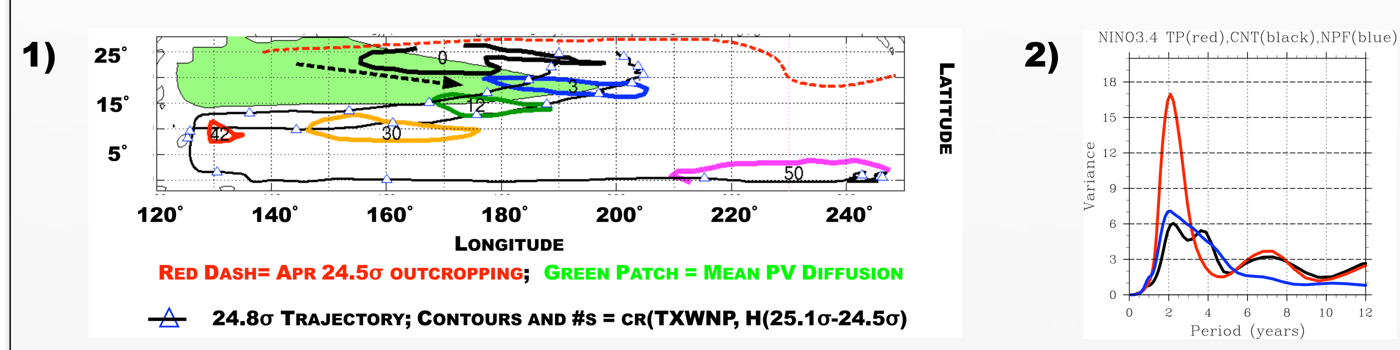


Evolution of the model SST and surface wind response to the NPO-related forcing during JFM of Yr (0) with forcing, and continuing through AMJ(0), JAS(0) and OND(1) without forcing.

North Pacific Air-Sea Interaction and Subduction

(Solomon et al. 2007, Climate Dyn.)

Forcing of the tropical Pacific from the North Pacific through ocean pathways was explored using an anomaly-coupled atmosphere-ocean model, where coupling was allowed in the entire Pacific basin (CNT), limited to the tropical Pacific (TP), or confined to the tropical Pacific with wind stresses and heat fluxes from CNT specified in the North Pacific (NPF). These experiments indicate that subducted temperature anomalies from the North Pacific reach the equator ~5 years later and influence ENSO variability.



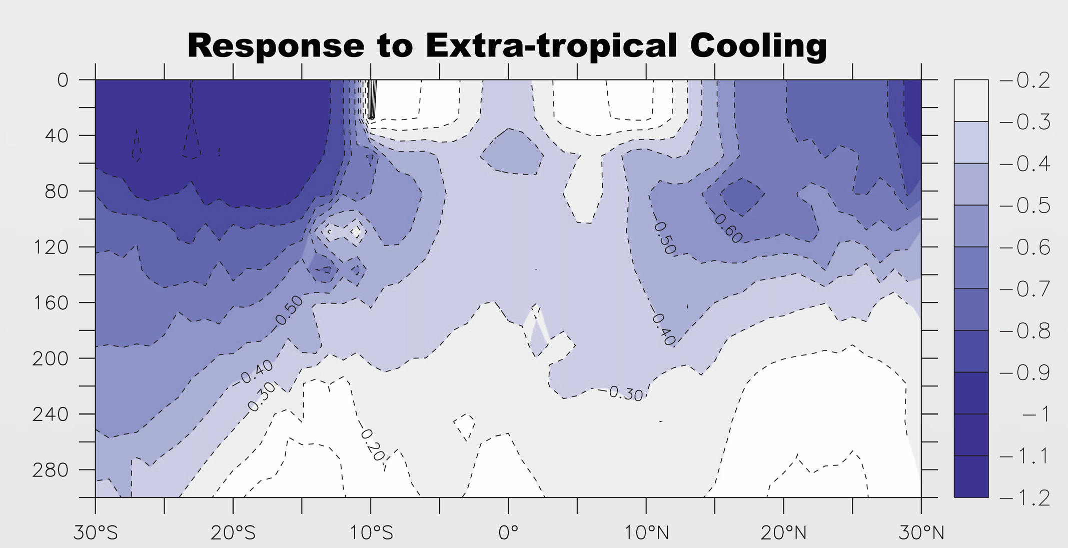
1) Ocean Pathway from the subtropical North Pacific to the equator. The signal starts at the outcropping line (red dash line), travels eastward along mean potential vorticity contours (green shading), and then follows advective pathways to the equator. Color contours show areas where the correlations exceed the 95% significance between wind stress in the subtropical North Pacific (140°E–150°W, 22°–36°N) and temperature (thickness) anomalies at lags of 0 to 50 months along the 25.7 isopycnal. The two black lines show trajectories along the 24.8 isopycnal with yearly advection intervals marked by triangles.

2) NINO3.4 SST spectra for the CNT, TP and NPF simulations.

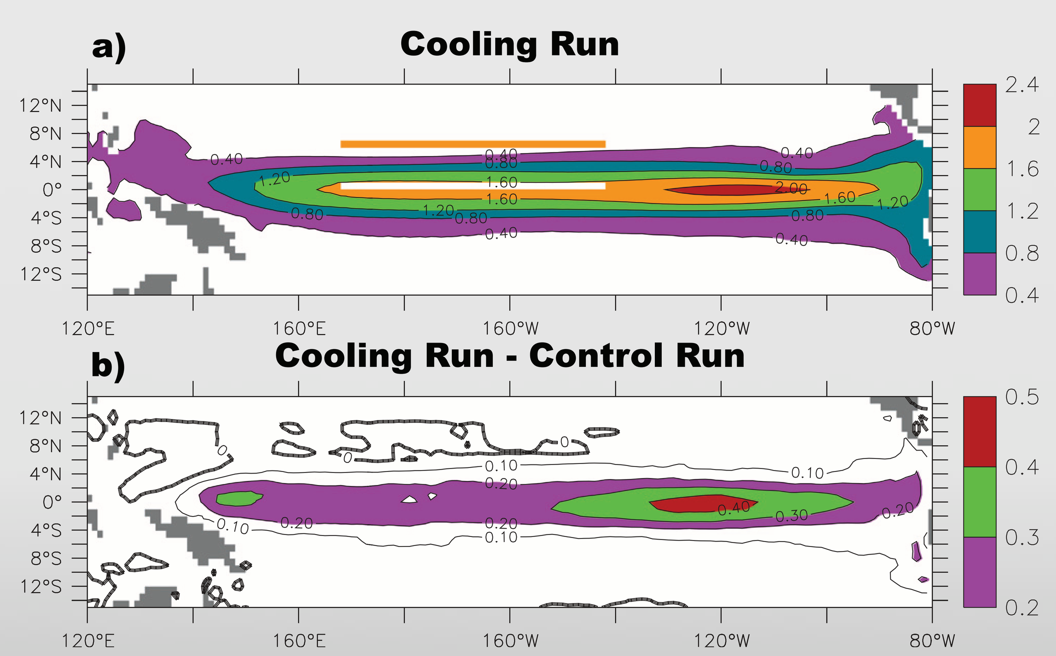
Sensitivity of ENSO to Remote Forcing

(Yu and Sun 2009, J. Climate)

Cooling of a coupled GCM over the Pacific poleward of 10°N–10°S results in an elevated level of ENSO variability. This cooling reduces the temperature of the water feeding the equatorial undercurrent and then upwelling cools the SSTs in the eastern equatorial Pacific. This enhances the zonal temperature gradient across the equatorial Pacific, destabilizing the coupled ocean–atmosphere system, resulting in stronger ENSO variability.



Depth–latitude section of the ocean temp difference between cooling and control simulation.



Standard deviation of SST for (a) cooling simulation and (b) cooling minus control simulation.